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Published <i>With international search report.</i>			
(54) Title: A PROCESS OF PRODUCING FIRE RESISTANT THERMOPLASTIC COMPOSITIONS AND COMPOSITIONS THUS OBTAINED			
(57) Abstract			
<p>A halogen-free and fire resistant thermoplastic composition is produced by preparing a blend comprising a halogen-free thermoplastic material containing both, cross-linkable and non-cross-linkable compounds, a fire resistant inorganic filler, a compatibilizing agent for said inorganic filler, and a radical generating agent; the blend is mixed and dynamically cured at a temperature above the decomposition temperature of said radical generating agent to obtain a partially cross-linked thermoplastic composition and a grafting of the compatibilizing agent on all the bulk of thermoplastic material.</p>			

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**A PROCESS OF PRODUCING FIRE RESISTANT THERMOPLASTIC COMPOSITIONS  
AND COMPOSITIONS THUS OBTAINED**

**FIELD OF THE INVENTION**

The present invention relates to a process of producing fire  
5 resistant thermoplastic based materials, to the polymer  
compositions thus obtained and to the products using said  
compositions.

In more detail, the invention relates to halogen-free  
thermoplastic materials that, filled with a high level of  
10 inorganic compounds, grafted in bulk with compatibilizing  
substances and dinamically "cured" with free radical generator  
catalysts, are both fire resistant and provided with  
surprisingly high thermomechanical properties.

**BACKGROUND OF THE INVENTION**

15 Halogen-free thermoplastic materials have a broad and useful  
range of mechanical properties. Among them, polyolefins are a  
chemically homogeneous class of polymers with a wide spectrum of  
properties and a low level of environmental impact, so their use  
is growing with an impressive rate and new materials, obtained  
20 from new catalitic systems, came into the market offering new  
applications.

These polymers, that contain mainly carbon and hydrogen, can  
burn and propagate the flame very easily and there has been a  
constant search for a way of removing this characteristic  
25 without compromising their mechanical properties and without  
transforming them in thermoset materials.

The higher the mechanical properties the larger the application  
field for these materials. With hard and stiff materials  
structural parts can be obtained like boxes, pipes, profiles,  
30 panels; elastic and flexible materials can be used for covering  
walls, wires or other objects for automotive, furnishing,  
building or electrical industries in which fire resistance  
without toxic substances emission in case of fire is requested.

A first, known, solution is to use inorganic compounds, i.e.

metal hydroxides (e.g. Mg and Al hydroxides), oxides and/or inorganic salts, having endothermical decomposition and releasing nonflammable gas (like water or carbon dioxide), and/or creating a protective shield when heated, as fillers in plastics or elastomers to impart flame retarding properties to said materials.

The flame retarding action of these inorganic compounds is based on physical reasons. Their endothermic thermal decomposition process subtracts heat to the burning bulk, reducing the release of flammable pyrolytic gases, and further diluting it with non flammable gas released by the inorganic compounds. In addition some of them can create a protective layer that acts as a shield against the flame propagation.

The main drawback of these inorganic fillers is that their effectiveness is pretty low and a high amount of filler is required to impart the polymer effective fire retarding properties (particulary with resins, like polyolefins, that can burn completely). In fact, the required amount of filler is so high that the mechanical properties of the final material are dramatically jeopardized. By selecting the most endothermic and gas releasing compounds, such as light metal hydroxides (aluminium or magnesium hydroxides) or boron containing compounds, or by using them in combination with other flame retardants compounds - which interfere in the combustion chemistry - a slight reduction in the amount of filler was obtained. However, the required amount of filler is still so high that the mechanical properties of the final composition are pretty poor.

In order to overcome these problems it was suggested to improve the adhesion between the filler and the polymer by adding compatibilizing agents that should have affinity to the polymer and the filler as well. As a matter of fact it is known that the mechanical properties of blends between polyolefins and metal hydroxides are improved when a moderate amount of a polyolefin containing succinic units, vinylsilane, or other polar groups,

as side substituents, are added, because its olefinic part remains into the bulk of the polymeric part and the succinic residue bonds to the filler either chemically (salification of the hydroxide) or by means of electrostatic interaction.

- 5 Alternatively, it was suggested to add to the polymer matrix compounds like peroxides, grafted silanes or sulphur that after the final product is obtained in its final shape, in a dedicated step can crosslink ("cure") the polymer matrix of the final product. By this process the mechanical properties of the 10 polymer are improved but the polymer is transformed into a thermoset material that can not be further processed or recycled. This method is used for example for the production of cables, pipes, tyres, foamed sheets, etc.

#### OBJECT OF THE INVENTION

- 15 The aim of the present invention is to improve the mechanical properties of halogen-free fire resistant thermoplastic materials in which the fire resistance is given by an inorganic filler, by means of a chemical modification of the polymeric matrix during the blend with the filler, and to substantially 20 maintain the thermoplastic characteristics of the starting materials in the final composition.

#### SUMMARY OF THE INVENTION

The invention relates to a reactive process to prepare halogen-free thermoplastic compositions having fire resistance 25 characteristics, according to claim 1.

According to a preferred aspect of the invention, the inorganic filler is selected from  $\text{Al}(\text{OH})_3$ ,  $\text{Mg}(\text{OH})_2$ ,  $\text{CaCO}_3$ , boric acid, borates,  $\text{CaO}$ , silica and mixtures thereof; the radical generating agent is a peroxide and the compatibilizing agent is 30 selected from maleic and fumaric acids, maleic and fumaric anhydrides and mixtures thereof.

This invention also concerns halogen-free, fire resistant thermoplastic compositions as obtainable according to the claimed process, wherein compatibilizing agents are grafted over 35 all the bulk of said thermoplastic material. The final

composition is thermoplastic and is partially crosslinked. The invention also relates to electric cables provided with a layer made with a fire resistant thermoplastic material according to the invention. Preferably, such layer is a shield.

- 5 The invention also relates to the use of a composition as above disclosed for the production of electric appliances and their parts, such as boxes, pipes, etc.

The invention provides several advantageous features.

As above mentioned, the invention process results in a final  
10 composition that is thermoplastic, i.e. it is further processable and recyclable. There thus is no need to give the product its final shape before curing it by heating the mixture and activating the peroxides; in fact a preferred shape for the invention composition is as pellets.

15 The invention compositions have surprisingly good properties, namely higher values of mechanical modulus, stress strain and elongation at break, impact behaviour, abrasion resistance, compression set and softening or distortion temperature, with respect to the properties of corresponding materials made  
20 according to known techniques.

These materials can be employed to obtain structural parts or to coat other objects to impart them the required characteristics of fire resistance features. They are processable by conventional processing technologies as: injection and  
25 co-injection molding, extrusion, co-extrusion, blow-molding, roto-molding, slush molding, thermoforming.

#### **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

According to the present invention the thermoplastic material useful for carrying out the process are selected from alpha-  
30 olefines homo and co-polymers such as ethylene, propylene, ethylene/propylene, propylene copolymers containing one or more alpha olefins with 2-10 carbon atoms (e.g. ethylene, 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-octene); EPM (ethylene/propylene) rubbers and EPDM (ethylene/propylene/dyene)  
35 rubbers; natural rubber; EVA (ethylene/vinylacetate);

ethylene/1-octene copolymer; polyenes homo and co-polymers such as polybutadiene; styrol/butadiene rubbers (SBR), hydrogenated styrol/butadiene copolymers; acrylonitrile/butadiene/styrene copolymer, their functionalized polymers; and mixtures thereof. The starting thermoplastic material must contain both crosslinkable and non-crosslinkable compounds. The amount of thermoplastic material is usually about 5-70 wt.%, in any case it is such as to bring to 100 the composition.

The inorganic fillers imparting fire resistance are those inorganic fillers that endothermically decompose with release of non-flammable gas and inert ashes. Examples of these fillers are aluminium trihydroxide, magnesium hydroxide, huntite  $[3\text{MgCO}_3 \times \text{CaCO}_3]$  or hydromagnesite  $[\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2 \times 4\text{H}_2\text{O}]$ , boric acid. Other suitable fillers are those that can vetrify like borate or hydrate borate, sodium bicarbonate, calcium oxide and silica. The fillers can be mixed together or diluted with inert materials like silica, or materials that decompose at higher temperatures than the polymer decomposition temperature, like calcium carbonate. Their total amount is within the range of 30-80 wt.%, typically from 40% to 75% by weight of the final blend. The compatibilizers are molecules with chemical affinity to the filler, and able to graft, with a chemical bond, the macromolecular backbone by means of a free radical catalyzed reaction. Typically these compatibilizers are unsaturated organic acids or esters, like acrylic, methacrylic, fumaric, maleic, citraconic or itaconic acid and esters, used in a concentration ranging between 0,005 and 10% by weight of the blend. Preferred compatibilizers are maleic and fumaric acids, maleic anhydride and mixtures thereof. Another class of useful compatibilizers are the maleinized polybutadienes or vinyl-methoxysilanes that can graft the macromolecular backbone accelerating and or promoting the crosslinking reaction, used in concentration till 15% of the total blend.

The preferred amount of compatibilizers is within the range of 0.01-15 wt.%.

The free radicals generator agentss are preferably organic peroxides like dicumil peroxide, 2,5-di(terbutylperoxi)-2,5-dimethylhexane, or other molecules with a strained bond that omolitically breaks upon temperature increase, like 2,3-5 dimethyl-2,3-diphenyl-butane. These free radical generator agents start radical chain reactions that both graft the compatibilizer molecule onto the macromolecules but also "cure" the polymer by crosslinking. Preferably, radical generating agents are provided in an amount of 0.01-2.0 wt.% of active 10 material.

Besides the above mentioned compounds, usual additives known in the plastics field such as antioxidants and stabylizers, plasticizers, lubricants, slipping agents and process coadiuvators are provided for in the invention composition. The 15 type and amount of these additives are directly derivable from known formulations and are not object of this invention.

According to the invention the process of preparing a thermoplastic composition that is fire resistant, free from halogens and really thermoplastic (i.e. further processable or 20 recyclable) provides to prepare a blend comprising: a halogen-free thermoplastic material containing both crosslinkable and non-crosslinkable compounds, a fire resistant inorganic filler, a compatibilizing agent for said inorganic filler, and a radical generating agent, and to dinamically cure said blend to obtain a 25 partially crosslinked thermoplastic composition.

"Dinamically curing" the above blend or mixture means that the blend is melted and kneaded at a temperature above the decomposition temperature of said radical generating agent in order to start and carry out the reticulation of the 30 macromolecules, i.e. the crosslinking, or the degradation of the macromolecules, according to their nature. The action of the radical generating agents occurs in the presence of the filler and of the compatibilizer to obtain the required grafting. The macromolecular structure of the thermoplastic material is 35 modified in a way that depends from its initial structure and

composition: with polymers having unsaturated carbon-carbon bonds like ethylene/propylene/diene rubber or styrene/butadiene rubber, or having more than 50% (moles) of ethylenic units in the backbone like polyethylene, ethylene/1-octene (or 1-hexene) 5 copolymers, ethylene/propylene rubber, ethylene/vinylacetate, hydrogenated styrene/butadiene rubber the main result of the radical chain reactions is a macromolecular crosslinking.  
If the macromolecular structure has no unsaturated carbon-carbon bonds and more than 50% (moles) of substituted vinyl units (- 10  $\text{CH}_2\text{-CHR-}$ , R different from H) like in polypropylene, the main radical reaction is a chain scission or degradation to give shorter chains.

This structural change control is a crucial point to improve the material characteristics that can be customized balancing the 15 degradation and the crosslinking by accurate polymer and additives choice.

For hard and stiff materials, polymers like polypropylene, that is degraded by radical generators, without any crosslinking reaction, are frequently employed. The control of this 20 degradation and some degree of crosslinking is possible by employing polymers rich in double bonds such as polybutadienes, polyalkenylanes, polyenes and EP(D)M rubbers that graft and join the macromolecules by free radical catalyzed reactions.

For flexible thermoplastic materials, a curable rubber is 25 frequently employed but the complete crosslinking that should transform the polymer in a termoset material is avoided by using some amount of polypropylene or other non-crosslinkable compound. The non-crosslinkable, degradable, compound substantially acts as a continuous phase in which the cured (or 30 crosslinked) phase is dispersed.

The formulation of the composition, i.e. the amounts of degradable polymers, curable polymers, peroxide and polymers rich in double bonds, is balanced according to the mechanical characteristic that are required for the final product. If 35 elastomeric properties are required, a greater amount of

crosslinkable compounds will be present in the initial thermoplastic material; if a rigid final product is required, the amount of degradable, non-crosslinkable (i.e. uncurable) compound will be greater than the amount of curable (crosslinkable) compound.

The invention process provides to carry out the mixing, melting, kneading, compatibilizing and curing/degrading of the blend components substantially in one step. The inorganic filler is usually added immediately after the reaction is started on the rest of the mixture, as disclosed by the following examples.

A preferred apparatus to carry out the process is an extruder, most preferably co-rotating twin screws extruders with a high dispersing and homogenization capacity, good temperature control and high ratio L/D, where L is the barrel length and D is the barrel diameter.

#### EXAMPLES

Several starting compounds in different amounts were processed according to the invention in a MARIS ® (Turin, Italy) TM 133 co-rotating twin screws extruder with L/D=40. The filler was added at about 1/3 of the barrel length through a side feeder. Antioxidants, if any, were added at 2/3 of the barrel length. A vacuum device was used to remove moisture and volatile by-products. The processed material was cut into pellets, cooled in water and dried in a spin dryer.

The samples for assessing the mechanical characteristics of the final material were obtained by injection molding according to ASTM D638, this being further evidence that all of the invention compositions are thermoplastic materials. The mechanical characteristics are listed in table 1 (elastomeric composition) and in table 2 (rigid compositions).

In table 1, examples 1, 5 and 6 are referring to state of the art processes. In 1 no peroxide or compatibilizing agent was used; in 5 and 6 the compatibilizing agent (comp<sup>1</sup>) was previously grafted on a polymer matrix (polypropylene) and subsequently added to the invention blend, the poor results are self evident,

also in ex.6 where a high amount of comp<sup>1</sup> was added.

Example 2 shows a comparative example in which peroxide only was used. Example 3 repeats the formulation of example 2, with the addition of maleic anhydride: the value of tension at break increased from 16 to 20 MPa.

5 This is the legenda for examples 1-8.

1) comp is a compatibilizing agent "POLYBOND 3150" ® by Uniroyal Chemical

2) Dicumyl peroxide by Oxido

10 3) Polypropylene homopolymer Daplen DS10 by PCD

4) Ethylene/1-octene copolymer Engage 8150m by DuPont-Dow Elastomers

5) Ethylene/propylene copolymer C0059 by Enichem Elastomeri

6) ethylene/propylene copolymer Stamylan 56M10 by DSM

15 7) ethylene/propylene random copolymer Daplen CHC 3007 by PCD

In table 2 examples 9-10 refer to rigid compositions and show the surprising results of invention composition 11 with respect to comparative examples 9 and 10.

The added legenda references for table 2 are:

20 8) ASTM 1238 (230°C, 2.16)

9) ASTM D 256

10) polypropylene homopolymer: Valtec MH113Y by Himont

11) EPDM: Dutral Ter 4038 by Enichem Elastomeri

TABLE I

Exmpl.	pp	elastomer	Mg(OH) <sub>2</sub>	CaCO <sub>3</sub>	MAh	comp <sup>1</sup>	perox. <sup>2</sup>	tens at break	elong at break	%
	%	%	%	%	%	%	%	MPa	MPa	%
1	7.48 <sup>3</sup>	29.79 <sup>4</sup>	60.5	2.23	0	0	0	6.5	1075	
2	7.48 <sup>3</sup>	29.79 <sup>4</sup>	60.5	2.18	0	0	0.05	16	225	
3	7.48 <sup>3</sup>	29.79 <sup>4</sup>	60.5	2.00	0.18	0	0.05	20	210	
4	7.48 <sup>3</sup>	29.79 <sup>4</sup>	60.5	1.96	0.18	0	0.09	23	198	
5	6.00 <sup>3</sup>	29.99 <sup>5</sup>	60.5	2.00	0	1.51	0	8.3	730	
6	6.00 <sup>3</sup>	15.8 <sup>6</sup>	60.5	2.00	0	15.7	0	14.1	130	
7	7.48 <sup>6</sup>	29.79 <sup>4</sup>	60.5	2.00	0.18	0	0.05	17.5	227	
8	7.48 <sup>7</sup>	29.79 <sup>4</sup>	60.5	2.00	0.18	0	0.05	19.4	218	

TABLE 2

Exmpl.	pp	elastomer	Mg(OH) <sub>2</sub>	CaCO <sub>3</sub>	MAh	comp <sup>1</sup>	perox <sup>2</sup>	MFI <sup>8</sup>	Flexural modulus MPa	IZOD <sup>9</sup> Notched 23°C J/m
	%	%	%	%	%	%	%	MPa	MPa	J/m
9	35 <sup>10</sup>	0	62	3	0	0	0	10	3800	28
10	34.47 <sup>10</sup>	0	62	3	0.5	0	0.03	12	3850	35
11	25 <sup>10</sup>	9.45 <sup>11</sup>	42	23	0.5	0	0.03	6	2500	45

## CLAIMS

1. A process for the preparation of a fire resistant thermoplastic composition, wherein a blend comprising a halogen-free thermoplastic material containing both crosslinkable and non-crosslinkable compounds, a fire resistant inorganic filler, a compatibilizing agent for said inorganic filler, and a radical generating agent, is mixed and dynamically cured at a temperature above the decomposition temperature of said radical generating agent to obtain a partially crosslinked thermoplastic composition.
2. A process according to claim 1, wherein said blend comprises 30-80 wt.% of said inorganic filler, 0.01-2.0 wt.% of active radical generating agent and 0.01-15 wt.% of compatibilizing agent.
3. A process according to claim 1 or 2, wherein said fire-resistant inorganic filler is selected from  $\text{Al(OH)}_3$ ,  $\text{Mg(OH)}_2$ ,  $\text{CaCO}_3$ , boric acid, borates,  $\text{CaO}$ , silica, and mixtures thereof; said radical generating agent is a peroxide and said compatibilizing agent is selected from maleic and fumaric acids, maleic anhydride and mixtures thereof.
4. A process according to any previous claim, wherein said non-crosslinkable compound comprises a propylene polymer and said crosslinkable compound is a polyene and/or a rubber selected from EPM and EPDM rubbers, natural rubber, EVA, polyalkenylanes, ethylene/1-octene copolymer, styrol/butadiene rubbers (SBR), hydrogenated styrol/butadiene copolymers, acrylonitrile-butadiene-styrene copolymer, their functionalized polymers, and mixtures thereof.
5. A process according to claim 4, wherein said rubber is oil extended and said thermoplastic material comprises a polymer rich in double bonds such as polybutadiene.
6. A process according to any previous claim, wherein a first blend is prepared, melted and kneaded to decompose said radical generating agent, said fire-resistant inorganic filler is added to said blend and heating and kneading of the complete blend is

continued to obtain said partially crosslinked thermoplastic composition.

7. A thermoplastic, fire resistant composition as obtainable according to the process of any claim 1 to 6, comprising a halogen-free thermoplastic material containing both a crosslinked and non-crosslinked portion, a fire resistant inorganic filler, a compatibilizing agent for said inorganic filler, said compatibilizing agent being grafted over all the bulk of said thermoplastic material.
- 10 8. A composition according to claim 7, in the form of pellets.
9. An electric cable, characterized in comprising a layer made of a composition according to claim 7.
10. The use of a composition according to claim 7 for the manufacture of fire resistant portions of electric appliances.

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/IT 97/00291

A. CLASSIFICATION OF SUBJECT MATTER					
IPC 6	C08L23/10	C08L23/16	C08K13/02	C08L51/00	C08L51/04
	H01B3/44				

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6	C08L	C08K	H01B	C08J
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 269 274 A (MITSUI PETROCHEMICAL IND) 1 June 1988 see examples 18-39	1,2,4,7
Y	---	1-4,7-10
X	EP 0 614 940 A (MITSUI PETROCHEMICAL IND) 14 September 1994 see examples E38,,E48-E72	1,2,4,7
Y	---	1-4,7-10
Y	EP 0 237 713 A (SUMITOMO BAKELITE CO) 23 September 1987 see page 3, line 13-23 see page 26, line 27 - page 27, line 5 ---	1-4,7-10
E	EP 0 822 223 A (COMMER SPA) 4 February 1998 see tab. 1, ex. 7, tab. 2, ex. 5,6 ---	1,4,7
	-/-	

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

21 July 1998

Date of mailing of the international search report

14.08.98

Name and mailing address of the ISA

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## INTERNATIONAL SEARCH REPORT

Intern	Application No
PCT/IT 97/00291	

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 280 761 A (SUMITOMO BAKELITE CO) 7 September 1988 see claim 1; example 1 ---	1,7
A	EP 0 462 680 A (MITSUI PETROCHEMICAL IND ;SHELL OIL CO (US)) 27 December 1991 see claim 1; example 1 ---	1,7
A	EP 0 370 517 A (NIPPON UNICAR CO LTD) 30 May 1990 see page 3, line 21-33; examples 1-16 ---	1,7
A	EP 0 370 518 A (NIPPON UNICAR CO LTD) 30 May 1990 see claim 1 ---	1,7
A	EP 0 546 841 A (NIPPON PETROCHEMICALS CO LTD) 16 June 1993 see claims 1,9,17,18,20; example 72 ---	1,7
A	KEONELLI, E. ET AL.: "Non-halogenated, flame retardant ..." KAUTSCHUK + GUMMI KUNSTSTOFFE, vol. 44, no. 10, 1991, page 960-962 XP002072157 see the whole document -----	1,7

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/IT 97/00291

### Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.: 6 because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:  
**IT IS UNCLEAR WHICH COMPONENTS A "FIRST BLEND" HAS TO COMPRIZE. CONSEQUENTLY SUCH A CLAIM IS NOT SEARCHABLE.**
  
3.  Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

#### Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

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